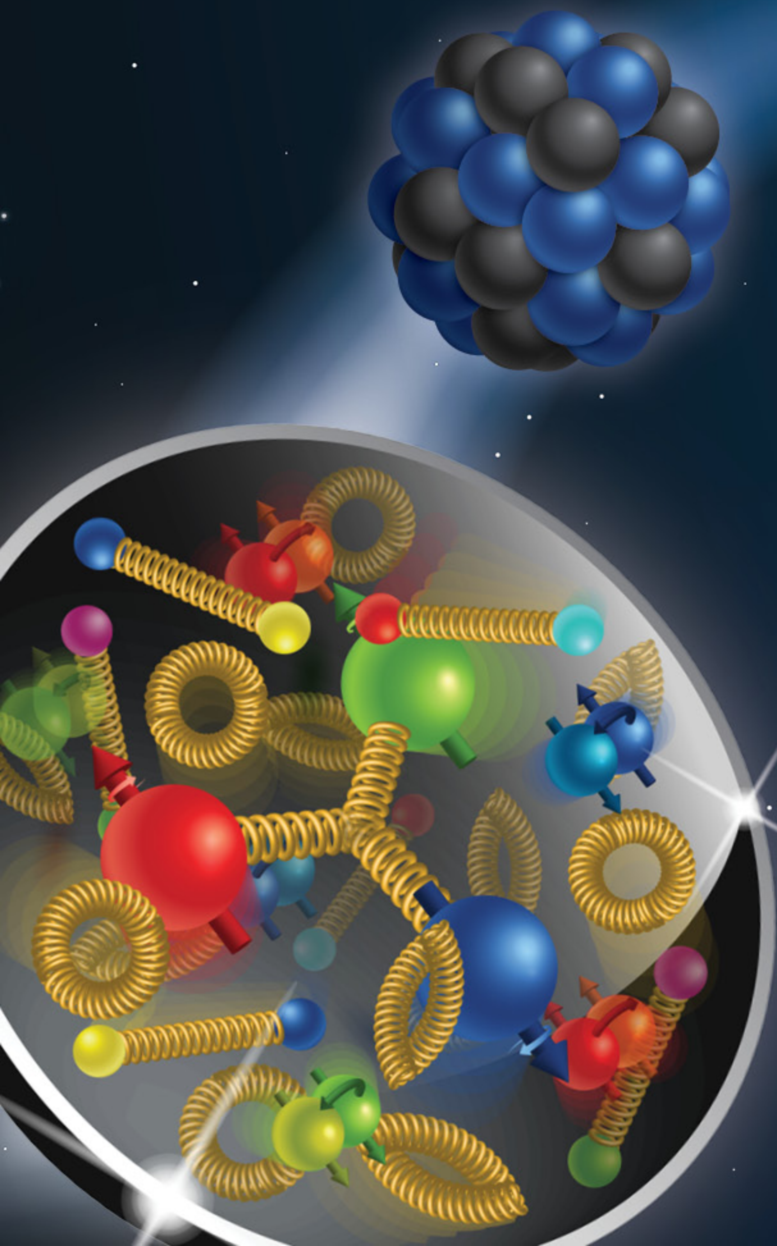


Far-Forward and Central Integration Summary

Alex Jentsch (BNL), Julia Furletova (JLAB), Michael Murray (Kansas), Alexander Kiselev (BNL), William Brooks (UTFSM)

2nd Yellow Report Meeting @ Pavia (remote)

May 20th-22nd, 2020

Electron Ion Collider

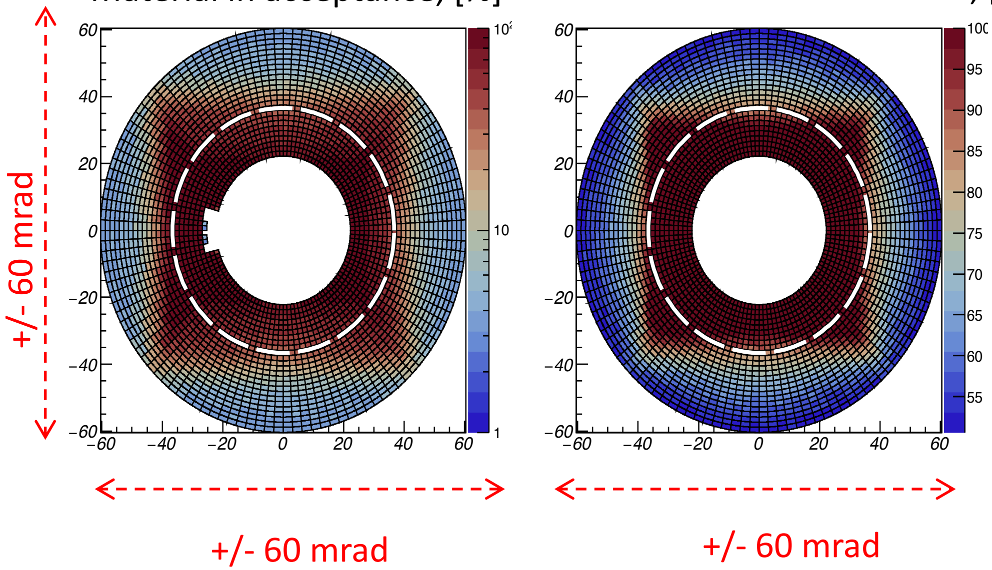
BROOKHAVEN NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY | Office of Science

Central Integration – Beam Pipe

Beampipe, electron acceptance

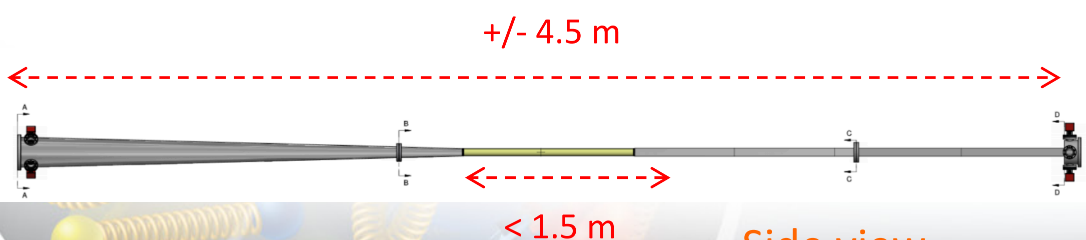
Material in acceptance, [%] First Si disk at this distance, [cm]



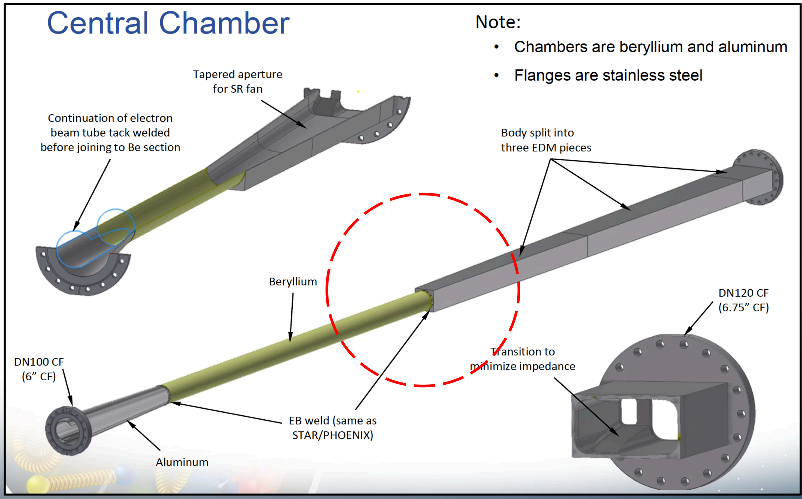
Central area (around IP) ok
Beryllium beampipe
Diameter 62.0 mm inner, 63.5 mm outer
Later: water cooling

Cones & rectangles: Al (needs improvement)

Plots: -4.5 < η < -3.5 band; white circle: η = -4.0



Side view

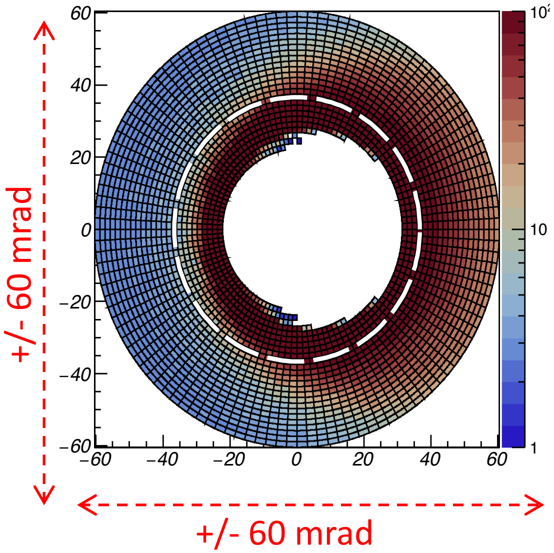


Key takeaway: there are improvements to be considered with the beampipe in the central/FF transition region.

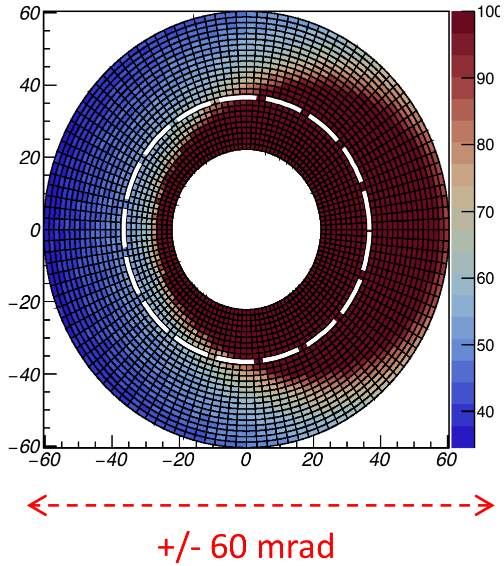
Central Integration – Beam Pipe

Beampipe, hadron acceptance

Material in acceptance, [%]



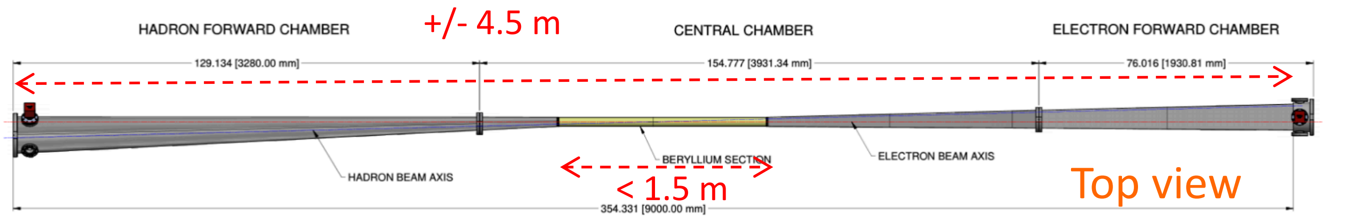
First Si disk at this distance, [cm]



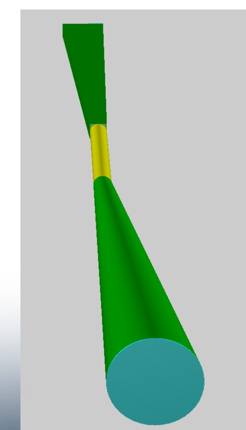
Central area (around IP) ok
Beryllium beampipe
Diameter 62.0 mm inner, 63.5 mm outer
Later: water cooling

H-pipe cone: Al (needs improvement)

Plots: 3.5 < η < 4.5 band; white circle: η = 4.0



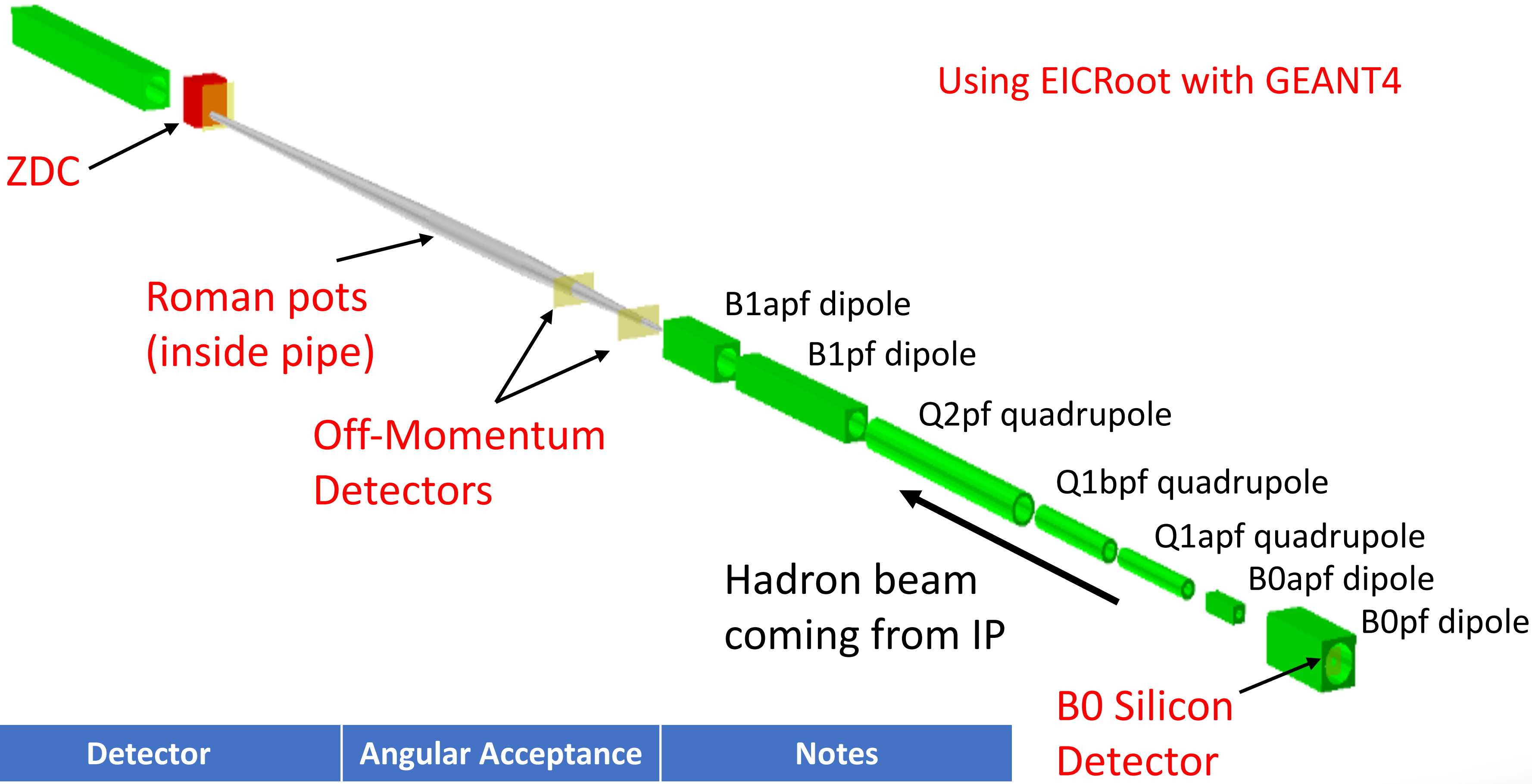
ROOT TGeo model used for the scans



Key takeaway: there are improvements to be considered with the beampipe in the central/FF transition region.

Slide from Yulia Furletova & A. Kiselev

Central Integration – Beam Pipe



Detector	Angular Acceptance	Notes
ZDC	$\boldsymbol{\theta} < 5.5$ mrad	About 4.0 mrad at $\varphi \sim \pi$
Roman Pots	$0.0 < \boldsymbol{\theta} < 5.0$ mrad	Need 10σ cut.
Off-Momentum Detectors	$0.0 < \boldsymbol{\theta} < 5.0$ mrad	Roughly $.4 < x_L < .6$
B0 Sensors	$5.5 < \boldsymbol{\theta} < 20.0$ mrad	Still need to optimize.

$$x_L = \frac{p_{z,nucleon}}{p_{z,beam}}$$

Slide from Alex Jentsch

Central Integration – Material Budget

Why it is important to keep low material budget for EIC detector and requirements:

- Compared to HEP, EIC is a low energy machine => with much lower momenta for charged particles
- Minimize multiple scattering for low-momenta charged particles in central detector
- Minimize unwanted photon conversion in front of calorimeter
- EIC HANDBOOK:

3.2 Detector Goals

In the previous section we listed the requirements that can be derived from the key physics measurements at an EIC in terms of rapidity coverage, momentum reach, and electron, photon, and hadron identification. What evolves is a detector with the following key features:

- Hermetic coverage, close to 4π acceptance (pseudo-rapidity range up to ± 4)
- Low material budget on the level of 3-5% of X/X_0 for the central tracker region
- Tracking momentum resolution in few % range
- Reliable electron ID
- Good $\pi/K/p$ separation in forward direction up to ~50 GeV/c
- High spatial resolution of primary vertex on the level of <20 microns

Central Integration – Material Budget

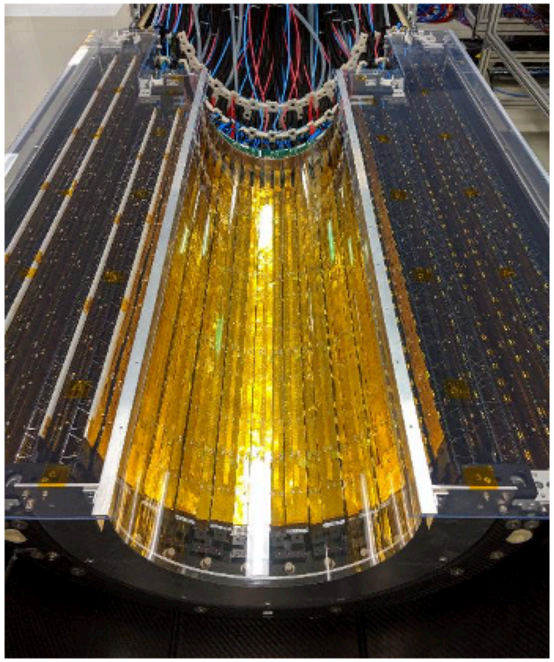
What to expect for radiation lengths for EIC structures - Current SOTA

Leo Greiner
(see next talk)

ITS2 Vertexing: ALICE ITS layers 0-2
0.3% per layer

- 50 um thick silicon
- Water cooled
- Aluminum conductor data/power flex-PCBs

ITS2 Barrel: ALICE ITS layers 3-6
~1.1% per layer



Key takeaway: Material budget concerns for a vertex tracker well-studied in other experiments. Especially important for EIC.

Slide from Yulia Furletova & Leo Greiner

Central Integration – Material Budget

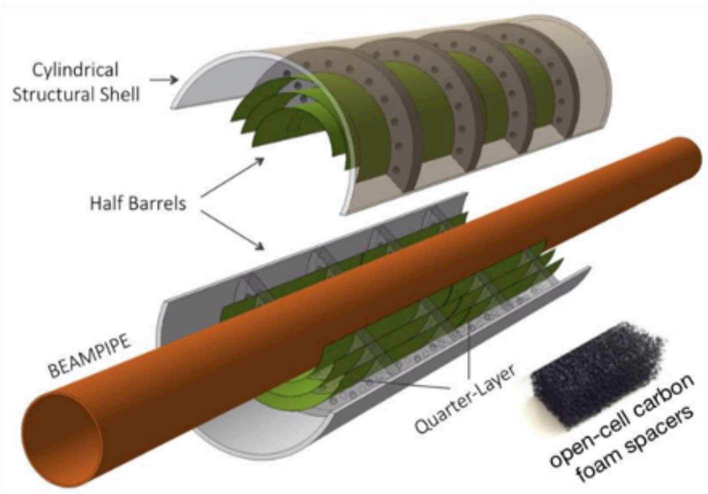
What to expect for radiation lengths for EIC structures - Vertexing

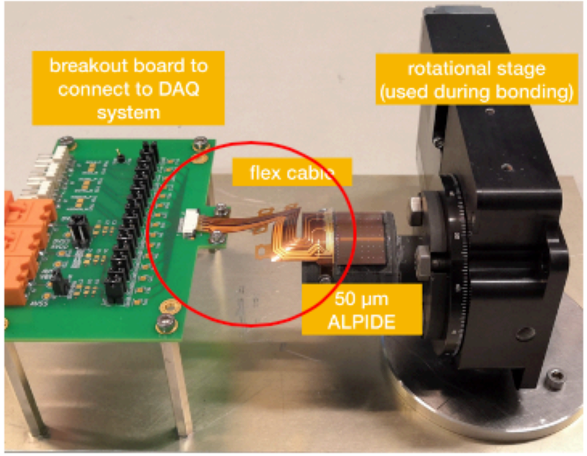
Can we do better?

Vertexing:
ITS3 concept

Potentially X/X0 ~ 0.05%

“bent” silicon
Detector concept





We will still have material at the end of the vertexing layers.
Reduced services compared to existing ITS layer 0-2 services. (less power needed)

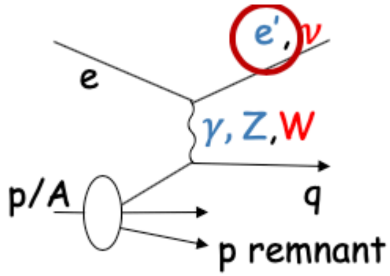
- Silicon thinned to <40um
- Air cooled
- Stitched – no connecting/power cable
- Carbon foam as support for layers

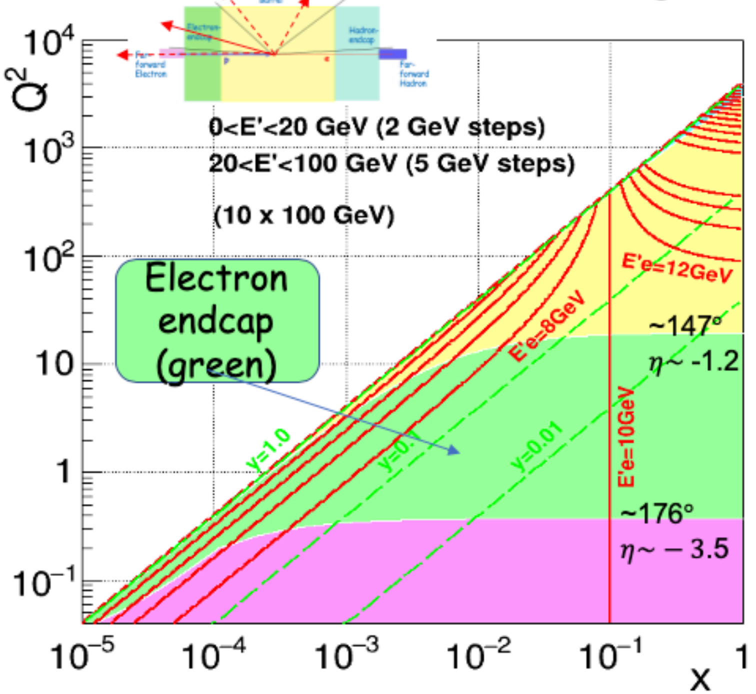
Key takeaway: Novel ideas under consideration to further improve material budget for a vertex tracker.

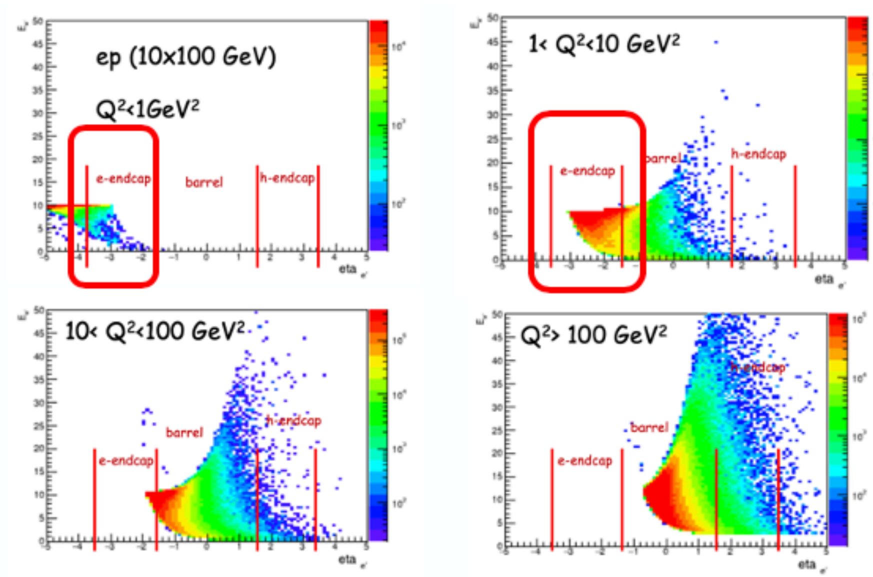
Slide from Leo Greiner

Central Integration – Material Budget

Electron Endcap







- Electrons mostly scatters to electron-endcap (green),
- Their energy/momentum are low (below initial e-beam energy)

$$Q^2_{\mathrm{EM}} = 2E_e E_{e'}\,(1+\cos\theta_{e'}),$$
$$y_{\mathrm{EM}} = 1 - \frac{E_{e'}}{2E_e}(1-\cos\theta_{e'}),$$
$$x = \frac{Q^2}{4E_e E_{\mathrm{ion}}}\frac{1}{y}$$

- Precision measurements of the electron scattered angle => defines precision measurements of Q^2

Scattered angle => Q^2

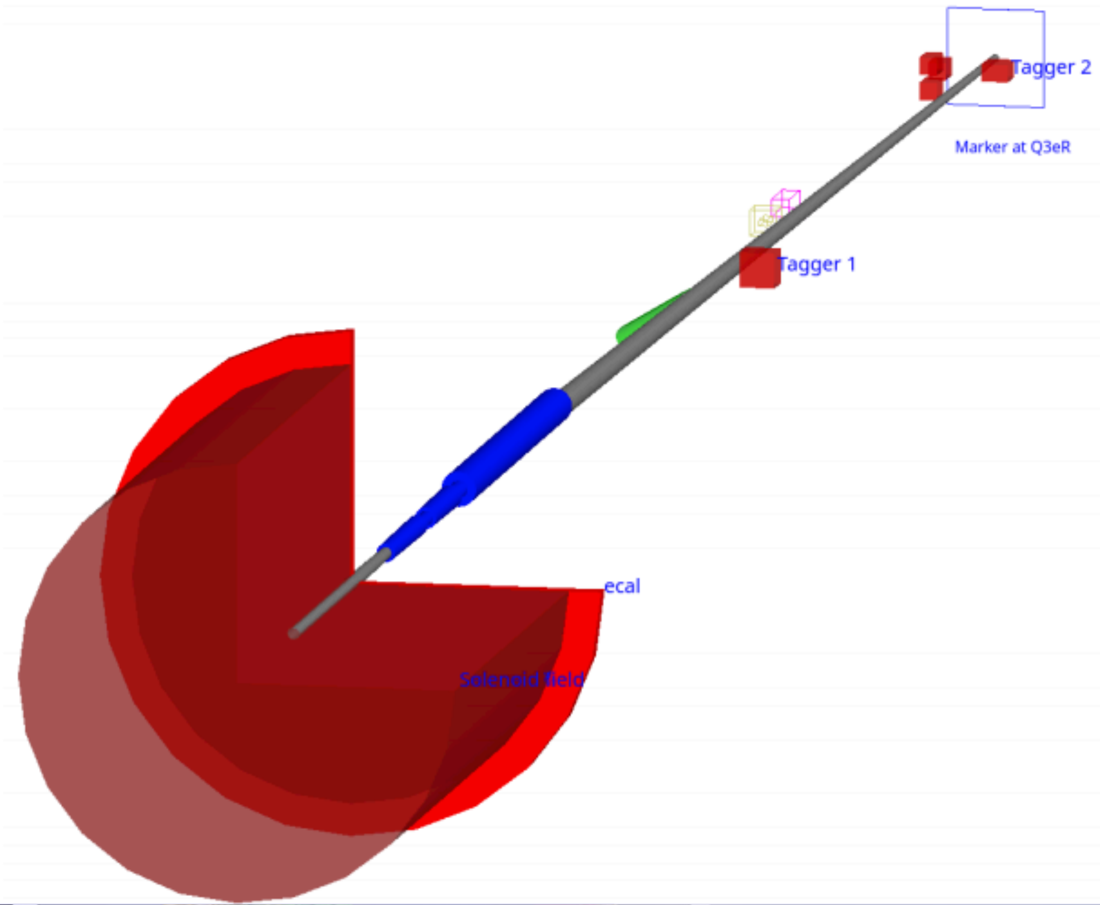
Key takeaway: Material budget concerns very important for electrons since we want precise measurements of x and Q2.

Slide from Yulia Furletova

Central Integration – Electrons

Low-Q2 tagger

Geant4 model for electron-outgoing IR



- Drift spaces in grey are transparent to all particles
- Tagger 1,2 and ECAL detectors mark hits by incoming particles
- Solenoid field uses the BeAST parametrization
- Beam magnets are shown in blue
- Components of luminosity monitor are on the opposite side to the taggers
- The layout ends with a marker at Q3eR position

Key takeaway: Studies well underway for optimal location(s), resolutions, and technology for low-Q2 tagger.

Slide from Jaroslav Adam

Central Integration - Electrons

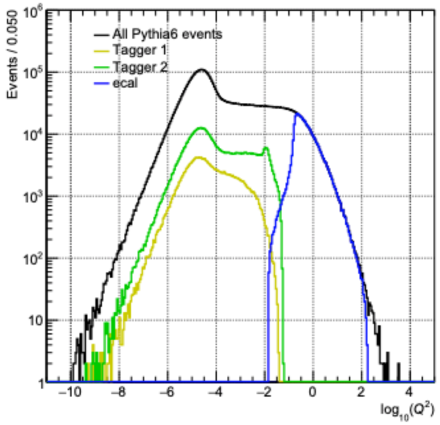


Figure: Q^2 with ECAL added

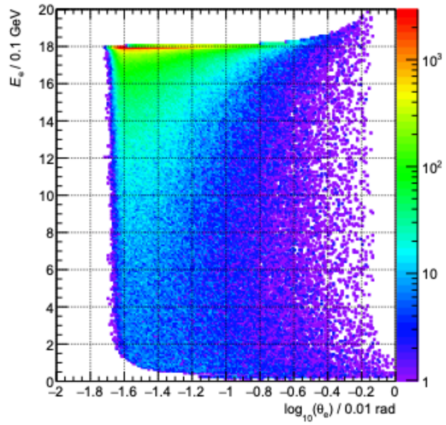


Figure: Energy and angles for ECAL

Figure: Tagger 1

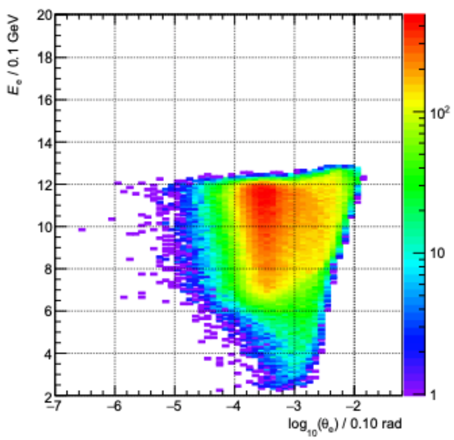
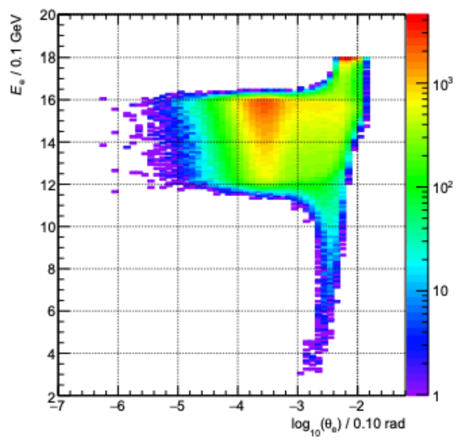


Figure: Tagger 2



Low-Q2 tagger

- The ECAL adds acceptance above the taggers
- Region of Q^2 from 10 to 10^{-2} GeV^2 is interesting for physics because it is transition from electroproduction (photon still virtual) to photoproduction (photon acts like real)
- The acceptance is driven by geometry (only solenoid field)
- For a large interval in Q^2 it is unity

Key takeaway: Combination of detector components needed to cover wide Q2 and energy range.

Slide from Jaroslav Adam

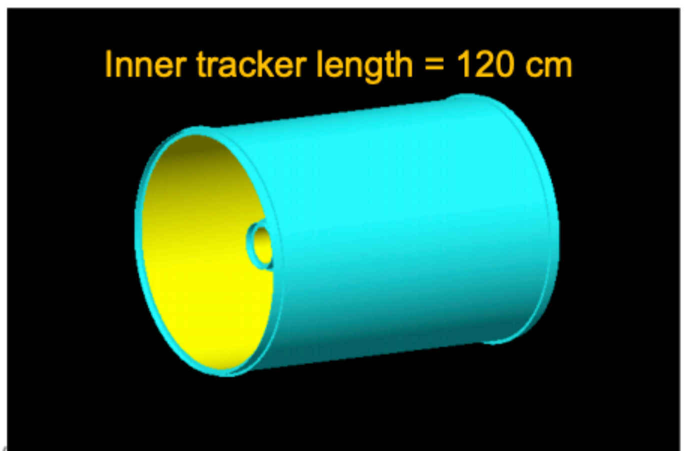
Central Integration – Material Budget

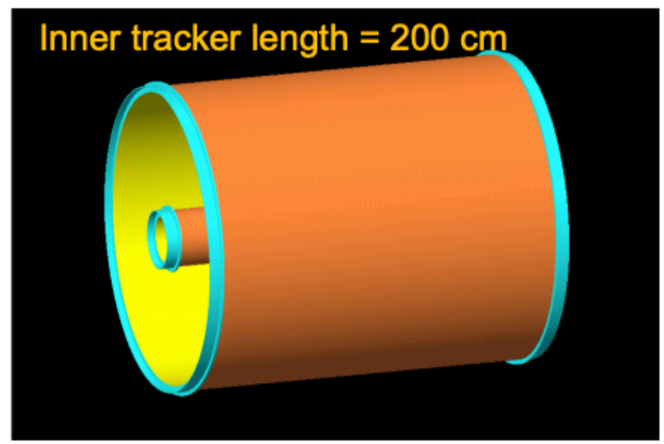
Tracking

Matt Posik for eRD6

- Support Ring Structure Geometry
  - Tube: thickness = 0.5 cm, length = 7.2 cm
  - Ring (inner): thickness = 1.6 cm, length = 1.2 cm
  - Ring (outer): thickness = 0.5 cm, length = 1.2 cm
- Material Scan
  - 2 micro-Rwell cylinders
    - Inner det. radius = 12.5 cm (length = 120 cm)
    - Outer det radius = 80.0 cm (length = 200 cm)

FIT mock prototype (support ring) Simulation implementation





Pav

2

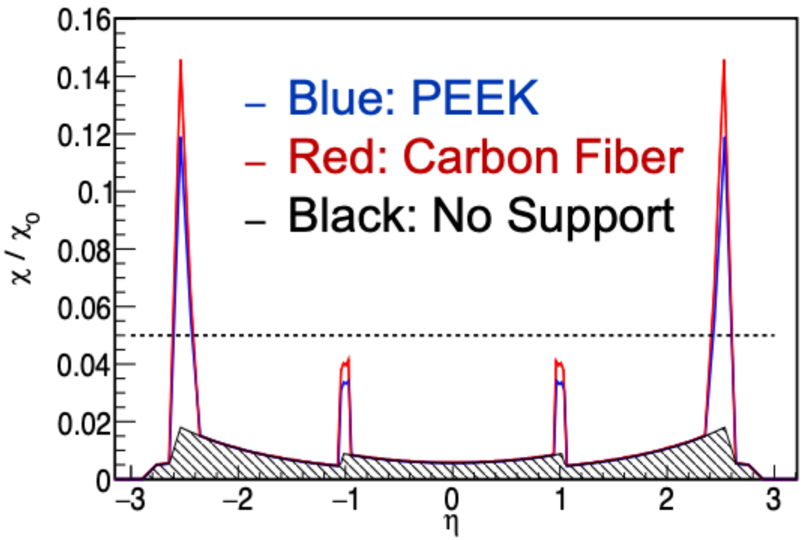
Central Integration – Material Budget

Tracking

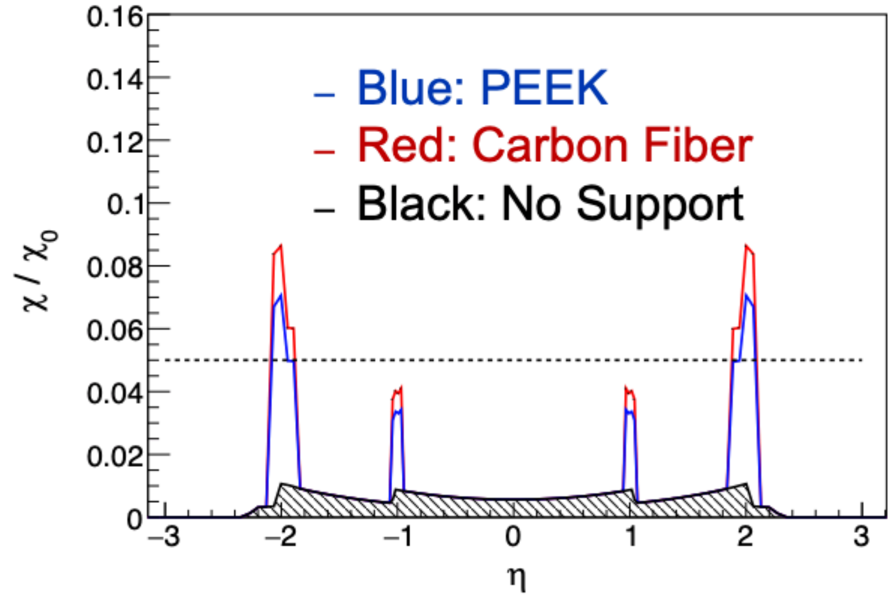
Matt Posik for eRD6

- Next Steps Implement
  - supports every ~ 50 cm
  - Readout card material
  - endcap

Inner tracker length = 2.0 m
Outer tracker length = 2.0 m



Inner tracker length = 1.2 m
Outer tracker length = 2.0 m

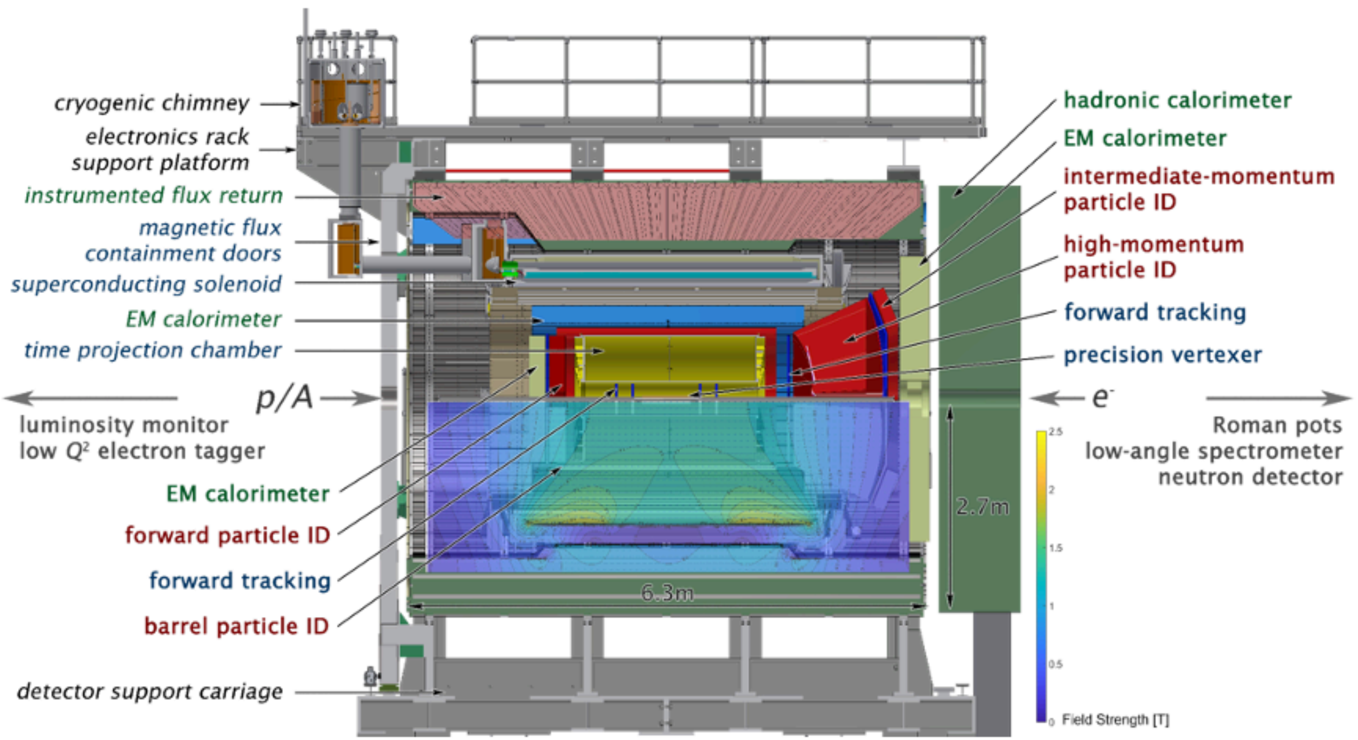


Key takeaway: Studies underway to study material budget concerns in a full collider detector with EIC kinematics.

Central Integration – Material Budget

One detector model used in this study

2014 concept: arXiv:1402.1209 [nucl-ex], 2018 update: sPH-cQCD-2018-001

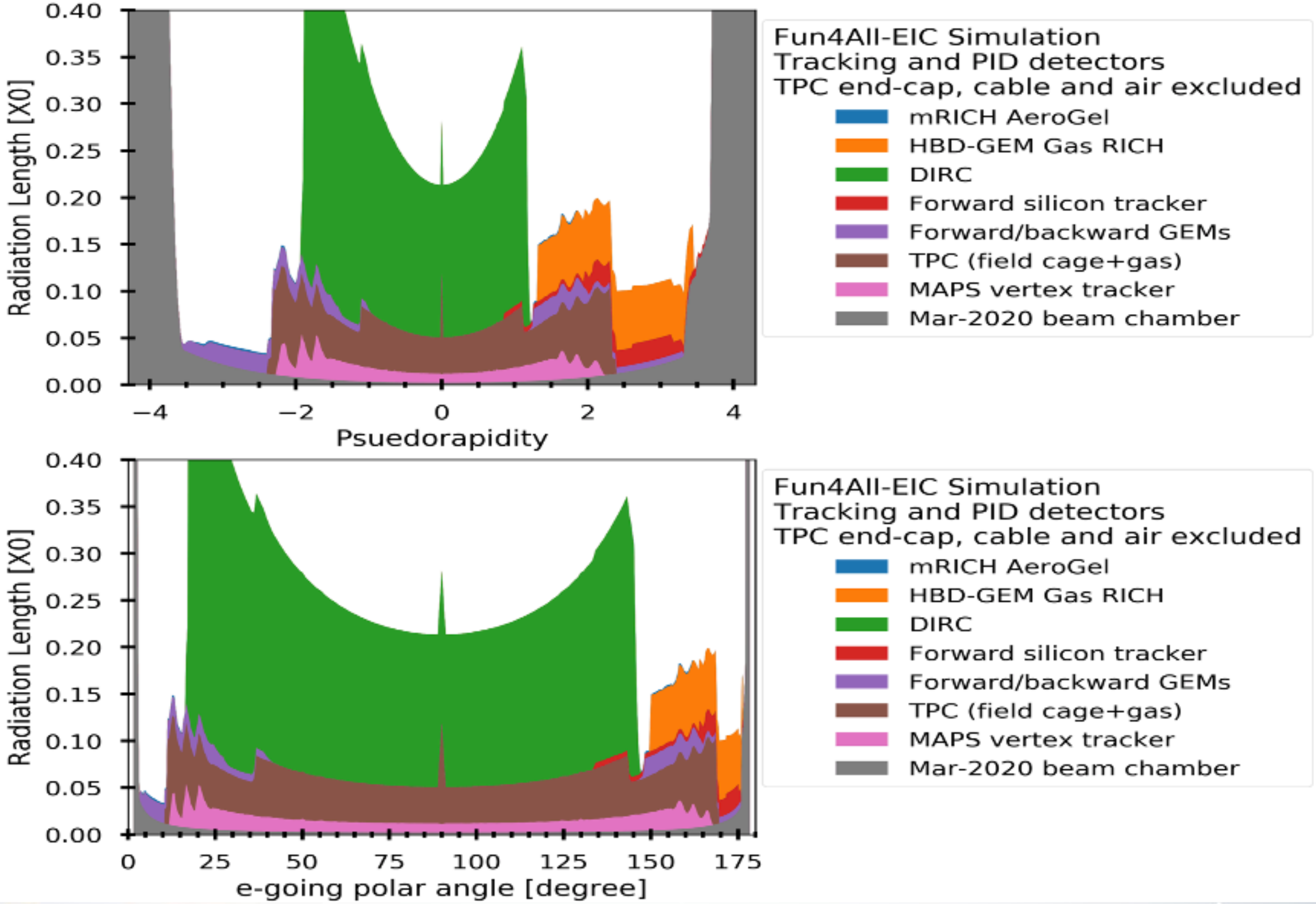


Slide from Jin Huang & Yulia Furletova

Central Integration – Material Budget

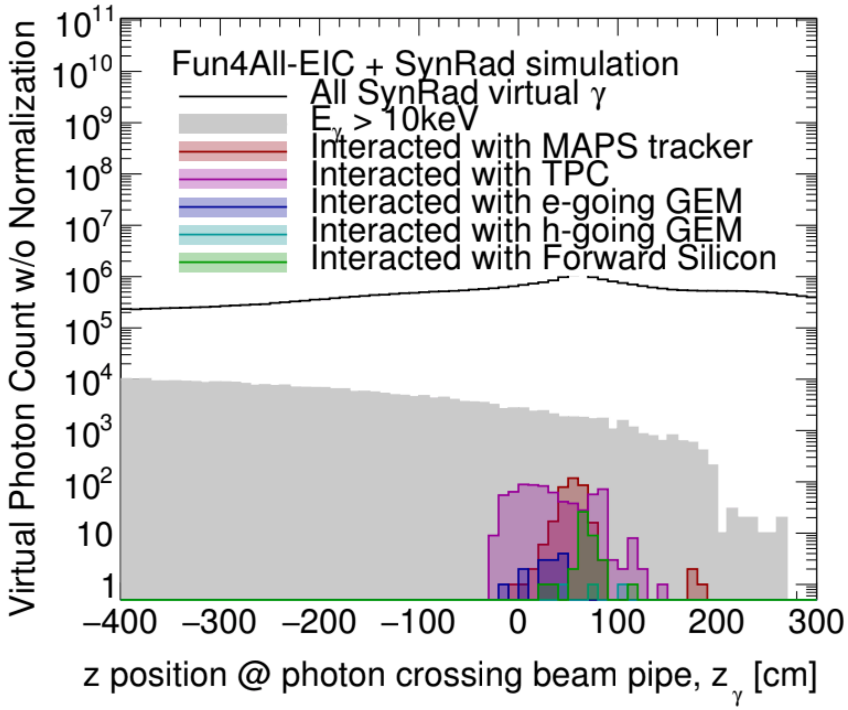
Reproduce: https://github.com/blackcathj/macros/tree/display-EIC-BeamPipe-materialscan/macros/g4simulations

Results

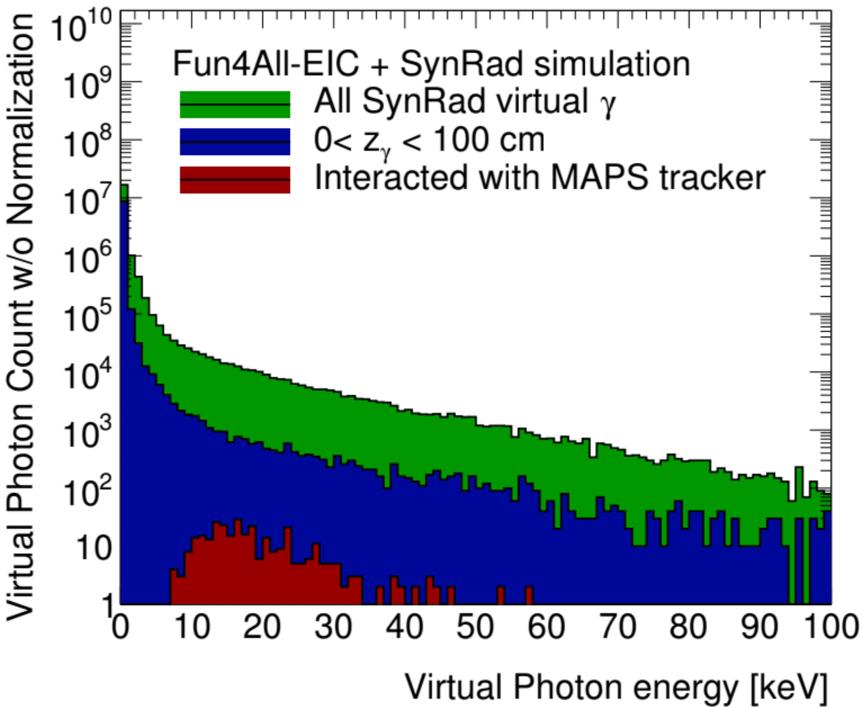


Slide from Jin Huang & Yulia Furletova

Central Integration – Synchrotron Radiation



Many detectors are venerable to synchrotron background, not just the ones immediately next to the beamline. These photon exit the beam pipe around -50 to 200 cm in z.



The higher energy portion of synchrotron photons are causing the problem. The interaction probability on the MAPS peak around 10keV.

Key takeaway: Synchrotron radiation a key concern for the EIC and can impact many detector components.

Takeaways from Central+FF

- We need the beam pipe design in the FF region to further determine space constraints and effects on acceptance.
  - Some optimizations are also needed in the beam pipe section inside the central detector region.
- Discussion still needs to be had about the aperture of the B0 magnet to maximize detector space (and a possible photon detector – see next few slides).
  - Also the transition between the central and FF regions – material budget, exit window for the B0, etc.
- Material budget is a major consideration that needs to go into detector design.
  - EIC kinematics will produce low momentum particles highly susceptible to multiple scattering.
- Need to decide on the rear side on layout of quads – has impact on electron measurements and Q2 range.

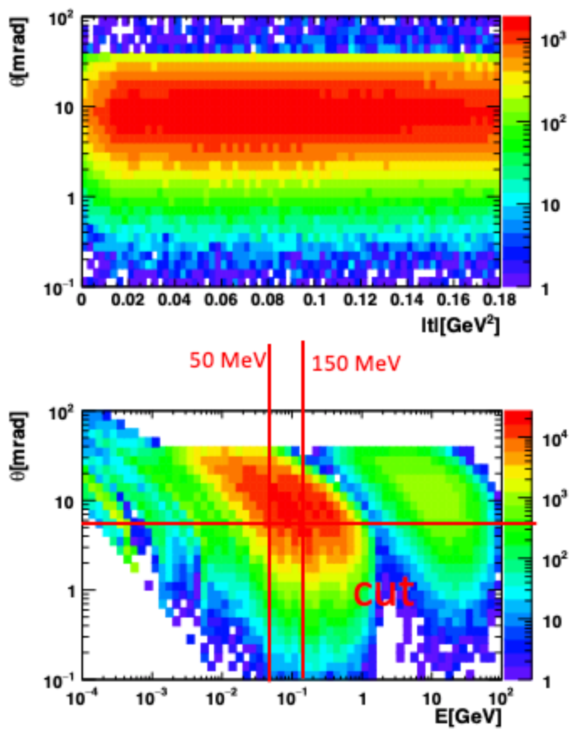
Status of Central Integration

- Lots of progress since Temple!
- Many considerations are now being discussed and models are being put together for quantitative analysis.
  - Full detector studies using sPHENIX for material budget considerations.
  - Lessons learned from ALICE ITS upgrade – not reinventing the wheel.
- Lots of discussion among different DWGs to understand each constraint and ensure it is included in the studies.

Joint Meeting with Central Integration DWG + PWG

Photon

Beagle Distribution before cuts



Photons to be detected in ECal part of ZDC Θ < 5.5 mrad

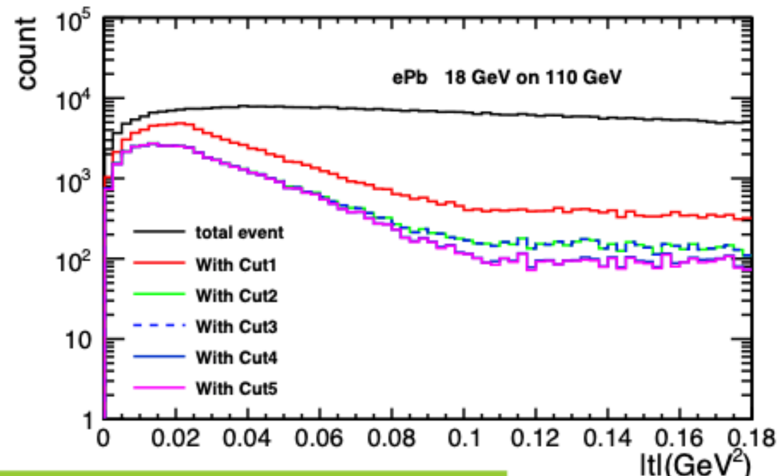
Challenge lowest detectable photon energy

Key takeaway: Low-energy photon measurement and incoherent breakup vetoing add further detector constraints and requirements.

Slide from Wan Chang

Joint Meeting with Central Integration DWG + PWG

Event distribution



The impact of the different detectors is studied by adding one requirement / cut after the other.

Cut1:
- no neutron in ZDC

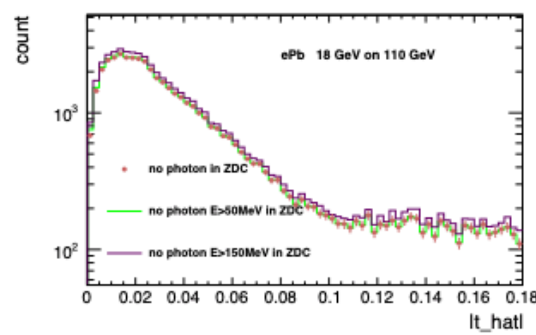
Cut2 :
- Cut1 + no photon ***E>50MeV*** in ZDC

Cut3:
- Cut2 + no proton in Roman Pots

Cut4:
- Cut3 + no proton in off-energy detector

Cut5:
- Cut4 + no proton in B0

Survived event count	
Total events	1000000
Cut1	132127
Cut2	66101
Cut3	66099
Cut4	61487
Cut5	55792



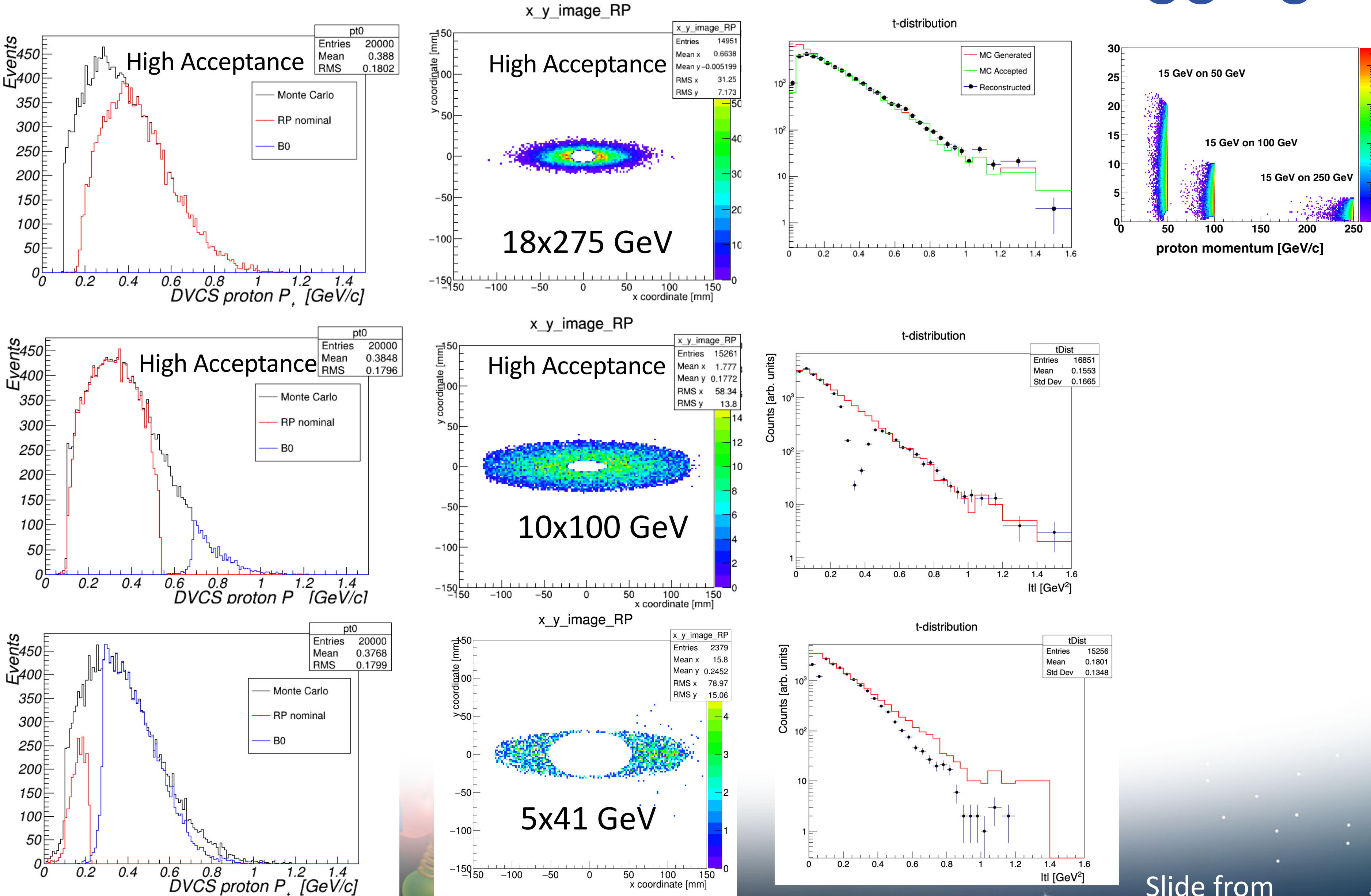
The survived events count after Cut2 with different energy cut on photon:

Survived event count	
E>150 MeV	71773
E>50MeV	66101
E>0 MeV	65278

Key takeaway: Improvements needed in incoherent veto power.

Slide from Wan Chang

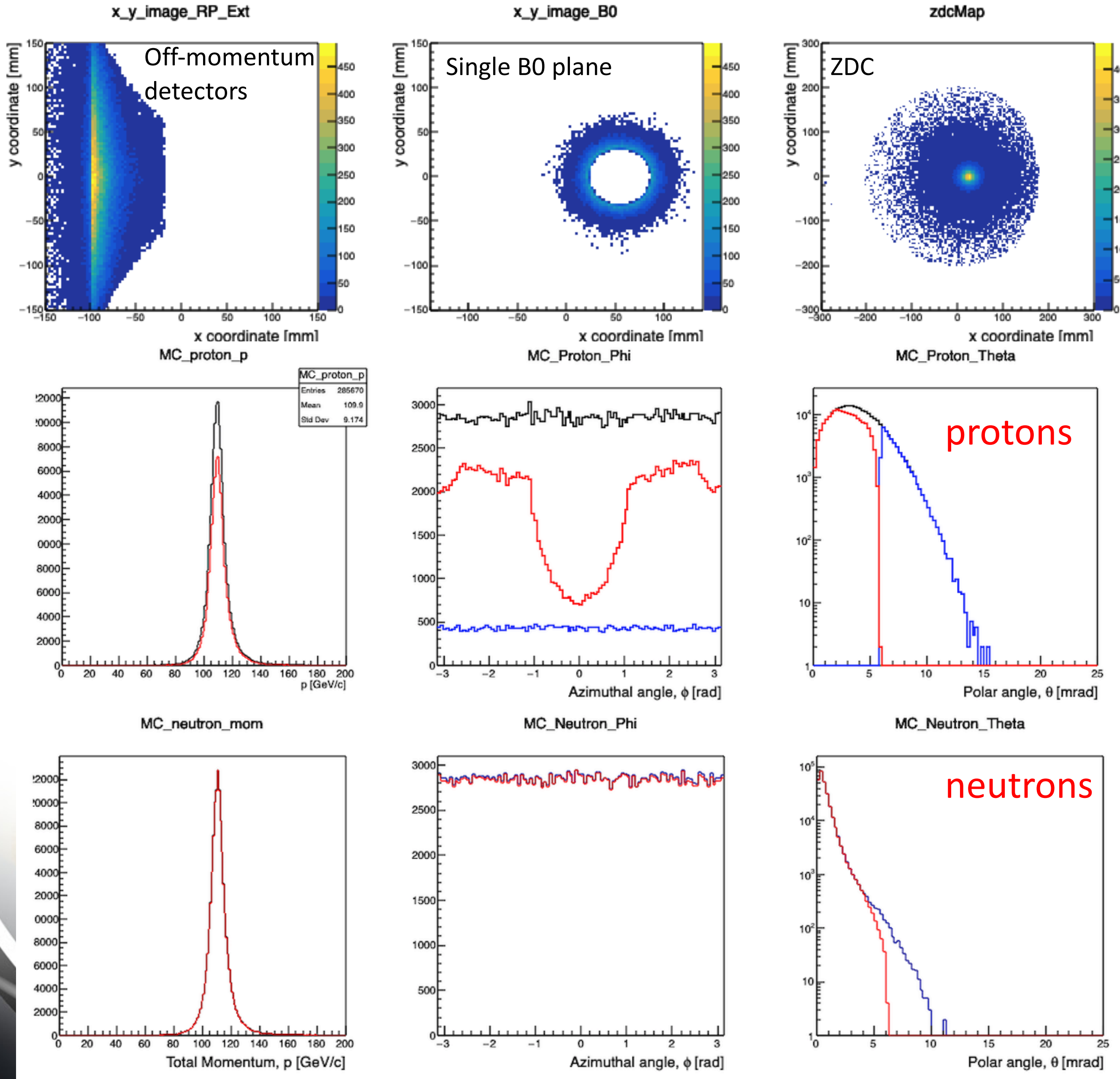
FF DWG + Exclusive + Diffractive/Tagging

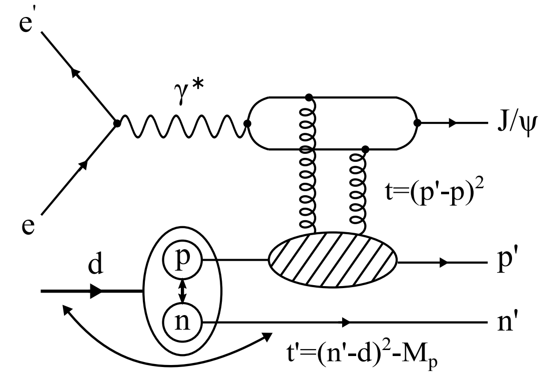


Key takeaway: DVCS acceptances and resolutions studied and help define requirements.

Slide from Alex Jentsch

Results from e+D nuclear breakup





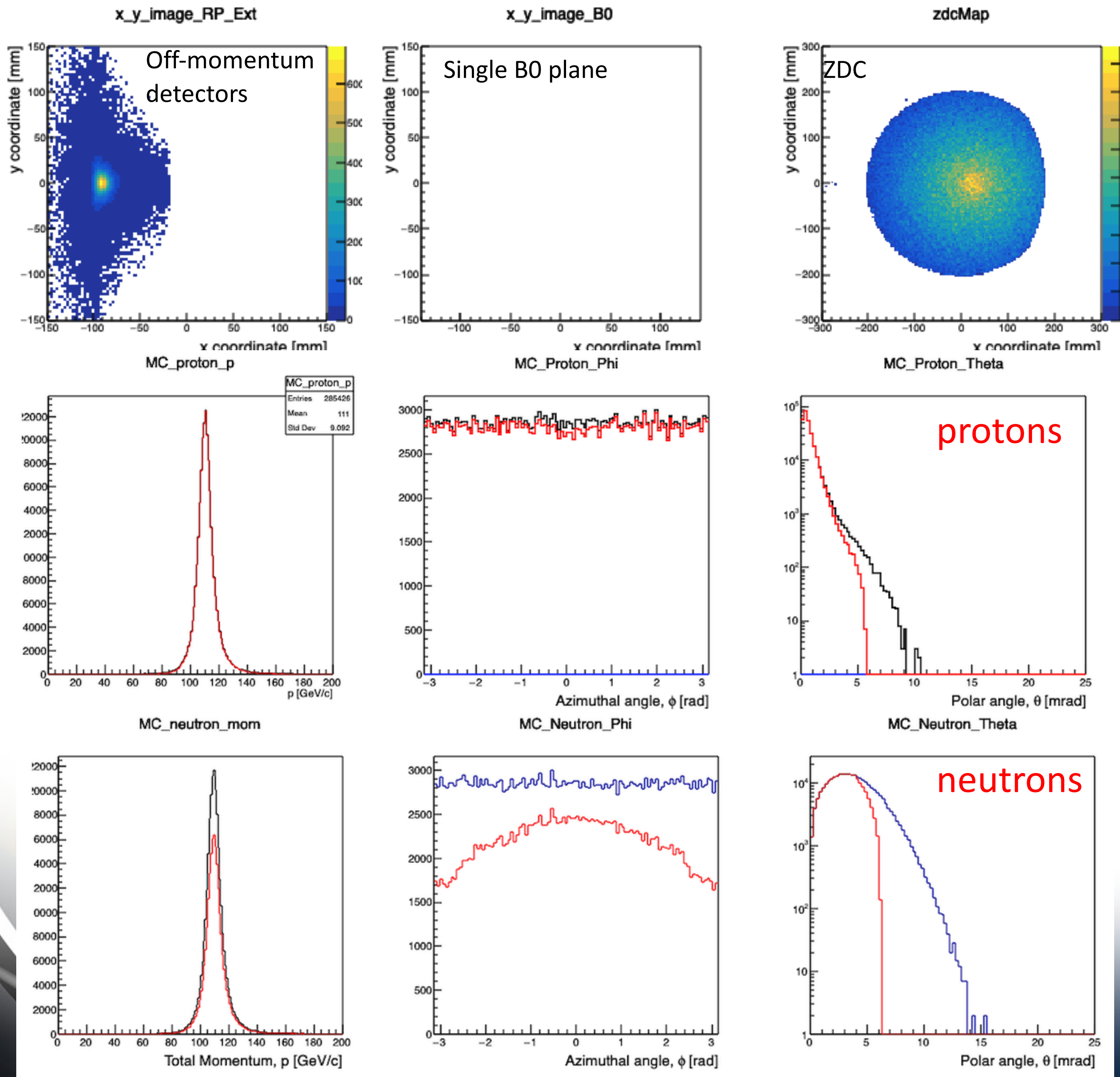
Particular process in BeAGLE: incoherent diffractive J/psi production off bounded nucleons.

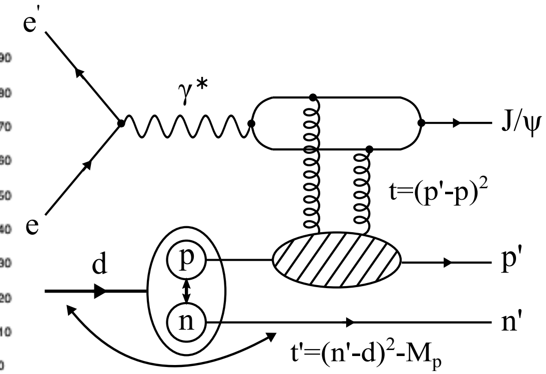
Neutron spectator case.

18x110GeV

Slide from Alex Jentsch

FF DWG + Exclusive + Diffractive/Tagging





Particular process in BeAGLE: incoherent diffractive J/psi production off bounded nucleons.

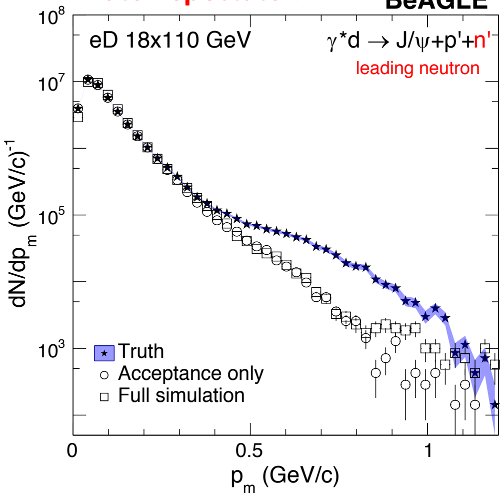
Proton spectator case.

18x110GeV

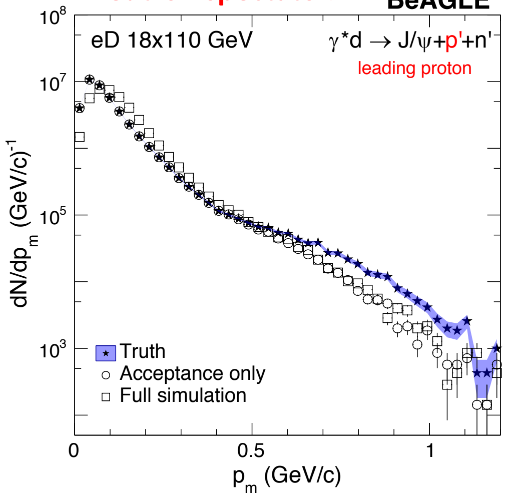
Slide from Alex Jentsch

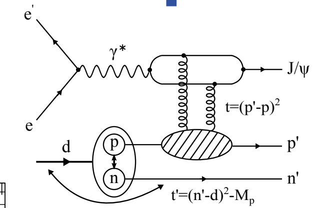
Results from e+D nuclear breakup

Proton spectator.

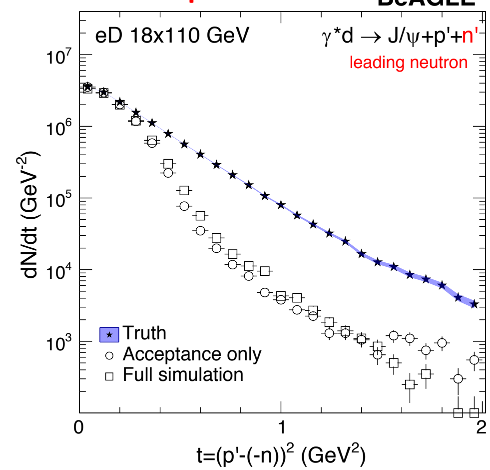


Neutron spectator.

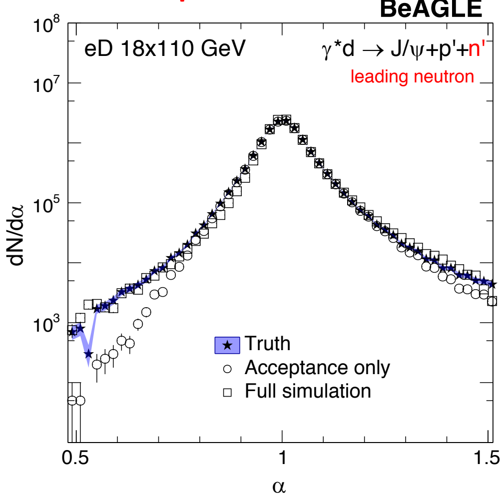




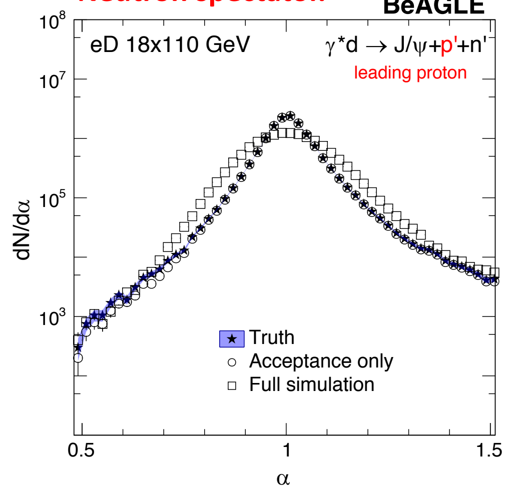
Proton spectator.



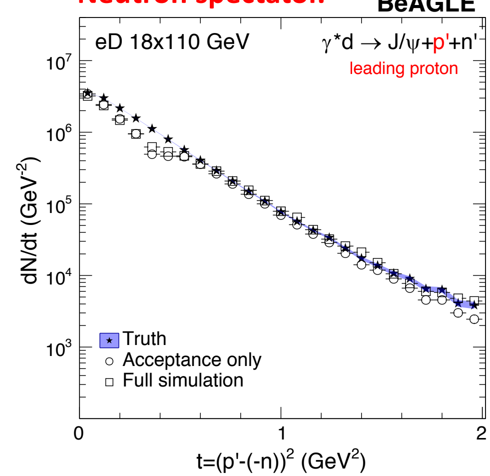
Proton spectator.



Neutron spectator.



Neutron spectator.



Key takeaway: Using full simulations, we are able to do full physics measurements. Paper to be on arXiv soon.

Slide from Alex Jentsch

Takeaways from FF+PWG

- There were several requests to have a uniform way to present acceptances for protons from all of the studies.
  - We will do this – we had a suggestion to parameterize as a function of (xL, pt).
- Many studies still need to be done with full simulations given the complexity of the FF region.
  - Given the limited human power – PWG should prioritize what MC samples they want processed in the next few months.
  - Communication between our group and the PWGs has been very smooth and we generally attend each other’s meetings.
- Working draft of our YR contribution in progress (on Overleaf).

Status of Far-Forward Group

- **<u>Tasks and deliverables</u>**
  - Understand detailed geometric acceptance with baseline IR design.
  - Propose baseline detector concepts for FF hadron & photon detection and study resolutions.
  - Iterate on the above points with possible, achievable improvements (e.g. ZDC energy resolution, pixel sizes, etc.)
  - Use studies to help inform second IR design to potentially cover gaps in the baseline IR.
    - The complementarity discussion has begun along these lines.
- **<u>Resources</u>**
  - People from both JLAB, BNL, and universities and other labs actively working on simulations.
  - People from JLAB, BNL, LANL, universities, etc. actively researching technology to meet requirements.
  - Computing resources in use at both BNL (RACF, EicRoot, Fun4All, etc.) and at JLAB (ESCalate, g4e, etc.).
- **<u>Plan for interaction with PWG and SWG</u>**
  - In progress – we have gotten MC input from both the exclusive and diffractive working groups that are being processed (or have already been processed) through the full IR simulation.